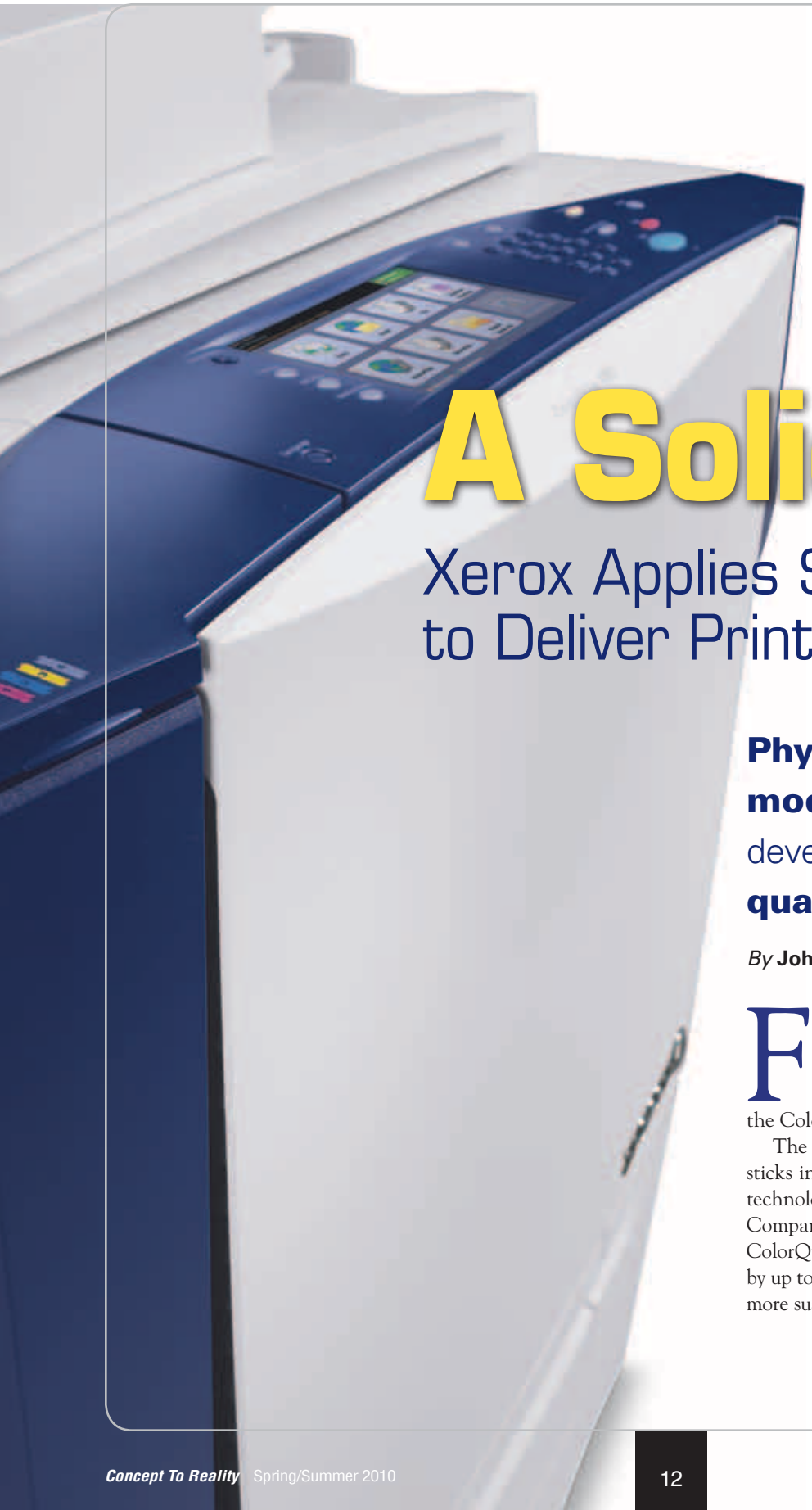


A Solid Idea:

Xerox Applies Simulation to Deliver Print Quality

Physical tests and virtual models enable Xerox to develop **cost-effective, quality,** color office printers.

By **John Wright**

From its humble beginnings as the Haloid Photography Company to its status as a Fortune 500 company, Xerox has focused on developing innovative, quality products. A case in point is the ColorQube™ 9200 Series multifunction printers.

The printers employ unique, crayon-like, solid ink sticks in place of toner or cartridges. The use of solid ink technology contributes to consistent, quality printing. Compared to comparable laser technologies, the ColorQube 9200 Series can cut the cost of color printing by up to 62% and reduce waste by 90% – contributing to a more sustainable printing solution.

The business-class ColorQube 9200 Series prints up to 85 pages per minute (ppm), copies up to 50 ppm, faxes, scans and emails. Under the hood, components are moving in complex patterns. The print heads jet ink onto a drum to form images, and ink is transferred and fixed onto paper from the drum with a pressure roller. The drum rotates, print heads scan across the drum and paper moves into place – simultaneously. This choreography must be precisely aligned and timed.

While the latest version of the printer was under development, the Xerox team wanted to understand how normal daily disturbances – such as printer door-slamming, general jostling and even the printer's operation – could throw off alignment while printing, causing visible defects in the prints. We also wanted to learn what we could do to minimize the misalignment with the least cost and risk.

We turned to sophisticated computer simulation to determine the impact of vibrations and disturbances during the ink-jetting process. To better understand our structural architecture and contributors to unwanted excitation, we collaborated with Altair ProductDesign.

A Fine-Tuned Process

To develop a printer that consistently delivered high-quality output, it was critical to minimize vibration at the pixel level. Unlike the automotive industry, which typically simulates at the millimeter level, we require analyses to be performed at the micron level.

To start, Xerox physically tested the printer's individual sub-systems. We placed accelerometers on the physical prototype of the ColorQube 9200 Series at key points where vibrations might cause problems. We wanted to know, for example, what would happen if someone opened and closed the document handler on the copier while it was operating. The data captured was important to assess the severity of different office use cases. After post-processing and reviewing the test results, Altair summarized these load cases into one worst-case scenario for testing 28 different "slam" events.

The next step was to develop a high-fidelity analytical model to confidently drive our design process to minimize vibration. This involved tearing down each sub-assembly to

Rethinking INK

Xerox's solid ink technology, introduced in 1991, revolutionizes office printing by providing a cartridge-free design and minimal packaging. The solid ink is resin-based, so the sticks are safe to handle by anyone. Similar to a crayon, the ink will not stain clothes or skin.

In operation, the solid ink is heated and becomes a liquid when it is ready to be jetted onto the printer's drum. Upon jetting, ink is instantly fused onto the paper using heat and pressure; this results in vivid image quality on any kind of media. When the ink sticks are totally consumed, nothing remains to be removed.

Solid ink printers and multifunction printers (MFPs) enable office staff to easily replace ink sticks instead of messy toner or inkjet cartridges. They also use far fewer consumables than laser printers because they eliminate waste bottles, replaceable imaging units and oiling units. What's more, the printers are environmentally responsible: they produce less waste than color laser printers, with no cartridges to dispose of and far less packaging to add to landfills. And, less energy is used to manufacture solid ink because of the simplicity of the design.

In addition to ease of use, the ColorQube 9200 Series market advantage is its pricing. Color printing becomes so affordable that offices no longer need a black-and-white laser printer and a separate color printer. When a ColorQube 9200 Series MFP prints pages requiring only a small amount of color, the cost per page is the same as black-and-white.

A Pioneer of Innovation

Xerox was founded in 1906 as the Haloid Photographic Company. Today, it is headquartered in Norwalk, CT, and employs 130,000 people. The company provides a broad portfolio of document technology, services and software as well as an array of business processes and IT outsourcing support. The company reported $485 million in income on revenue of $22 billion in 2009.

Xerox introduced the first plain paper photocopier, the Xerox 914, in 1959. Ten years later, it invented laser printing. In the 1970s, the Xerox Palo Alto Research Center helped launch the computer industry by developing the graphical user interface, mouse and the Internet.

The company dedicates roughly 5% of its revenue to R&D. Xerox has 5,000 scientists and engineers worldwide and has been issued more than 50,000 patents.

In the design of the ColorQube 9200 Series printer, Xerox turned to simulation to control vibration at the pixel level.

its constituent parts and performing natural frequency tests at each step of re-assembly with a tuning fork.

Simultaneously at the testing site, Altair built the finite-element model and solved for the natural frequencies at each step of re-assembly as it was physically tested to ensure the highest degree of correlation. This effort involved updating the model parameters to account for unrepresented stiffness influencers in the analytical model such as surface-to-surface contact, X-axis bearing stiffness, lumped masses, spring stiffnesses and even the mass of the accelerometers and parts to the gram. All analyses were performed using the applications in the Altair HyperWorks CAE software suite including HyperMesh and HyperView for pre- and post-processing and RADIOSS to solve for the natural frequencies.

Eventually, the final virtual assembly comprised hundreds of thousands of elements that represented over 100 different parts within the machine. This high-fidelity model was designed to calculate the relative displacement between the print head and drum during jetting and to offer design directions for minimizing that motion.

In all, Altair ProductDesign consultants used the virtual simulation model to test 12 different design variables yielding excitation curves that graphed exactly how each of

the critical points on the ColorQube 9200 Series reacted to everyday shipping and office use cases. The alternative to a simulation-driven design approach would have required fabricating and testing numerous physical prototypes. Time-to-market pressure in the electronics industry makes the traditional make-it and break-it approach obsolete.

Dynamic Results

The Altair ProductDesign team turned up some surprising and cost-saving results for Xerox.

We had been planning to incorporate bushings to dampen vibrations, but the analysis showed these bushings had very little effect on print quality. Altair also tested a number of design variables to show which design options would be the most sensitive to vibrations in the drum and print head. They found that the preload, spring stiffness, materials and gauges being used had minimal effects in the lower frequency ranges, where most of our concern had been.

The analysis also recommended a number of simple and no-cost alterations – like a mounting change, the addition of a gusset and stiffening of the frame as ways to reduce the displacement caused by vibrations.

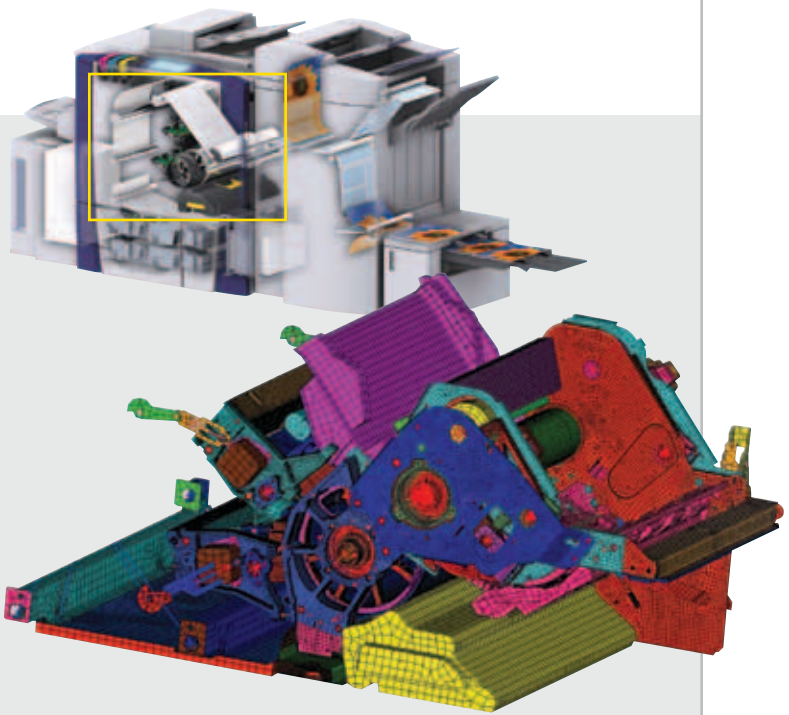
Altair ProductDesign's simulation results were instrumental in enabling Xerox to take some cost out of the product. For example, the dampers we were originally going to include in the product would have complicated the design's space and structure and added cost. The analysis demonstrated that those isolators were not needed.

We were able to perform multiple analyses at the same time with Altair's simulation model. It was easy to add or remove different design cases and come up with conclusive results on each one.

Moreover, if Xerox had to build and test physical prototypes from scratch instead of using Altair's simulation model, the job would have added months to the program.

This kind of optimization effort would add value as it allows for the investigation of new and radical architectures quickly and cost-effectively.

In a separate series of analyses, Altair also simulated drop tests to determine how a five-foot fall from a truck during unloading would affect the product's structural integrity. Xerox used those results to add protection to our printer packaging.



The Xerox team collaborated with Altair ProductDesign, which developed analytical models of the Xerox ColorQube 9200 Series multifunction printer to determine the impact of vibrations during the ink-jetting process.

In Sync

Throughout the simulation testing, the most important success factor was collaboration. Design teams from Xerox and Altair ProductDesign worked efficiently to synchronize the exchange of information between physical and virtual models and to run the tests in ways that examined and eliminated potential problems to the fullest extent possible.

Xerox laid out a roadmap at the beginning of the project, from which we could see what we needed to provide, as well as what to expect and when from Altair. Altair's work was crisply executed and data driven, and it never lost sight of the objective.

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For more information about Xerox and Altair ProductDesign, visit *www.altair.com/c2r* or check 04 or 05 on the reply card.